QUAKESIM Understanding Earthquake Processes

Complex Faulting Across the Los Angeles Portion of the Pacific-North American Plate Boundary

Andrea Donnellan
Jet Propulsion Laboratory, California Institute of Technology and University of Southern California

Jay Parker, Robert Granat, and Maggi Glasscoe
Jet Propulsion Laboratory, California Institute of Technology

Greg Lyzenga
Jet Propulsion Laboratory, California Institute of Technology and Harvey Mudd College

Lisa Grant Ludwig
University of California, Irvine

John Rundle
University of California, Davis

APEC Cooperation for Earthquake Simulation (ACES)
Workshop on Advances in Simulation of Multihazards
Computational Technology & Quake Simulations
Maui, Hawaii, May 1-5, 2011

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QuakeSim Focus

- Modeling and understanding of earthquake and tectonic processes with a goal of improving earthquake forecasting
- Interseismic part of the earthquake cycle
  - With coseismic offsets
- Modeling and pattern analysis exploration environment
- Accessible NASA crustal deformation data
  - Integrated with distributed heterogeneous data sources
    - Seismic and geologic data
    - Modeling, simulation, and pattern analysis tools
  - Prepare for large volumes of NASA data

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Focusing Attention on Future Earthquake Likelihood

November 2007 Abstract in proposal to NASA:

We propose to observe seismically and tectonically active regions in northern and southern California using UAVSAR to support EarthScope activities. We will test the earthquake forecasting methodology developed by Rundle through NASA's QuakeSim project by observing regions indicated as having high probability for earthquakes in the near future (5–10 years). The UAVSAR flights will serve as a baseline for pre-earthquake activity. Should an earthquake occur during the course of this project, we will also be able to observe postseismic motions associated with the earthquakes.

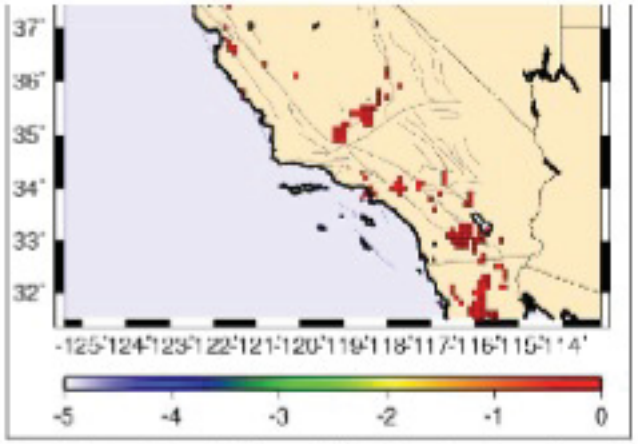

Figure 1. Pattern informatics (PI) map for the California and surrounding region cropped to better show the regions of interest in this proposal. Data from 1950–2005 were used. Map is a forecast of where earthquakes are expected to occur during a future time window of 5–10 years. Color figure from Holliday et al., 2007.

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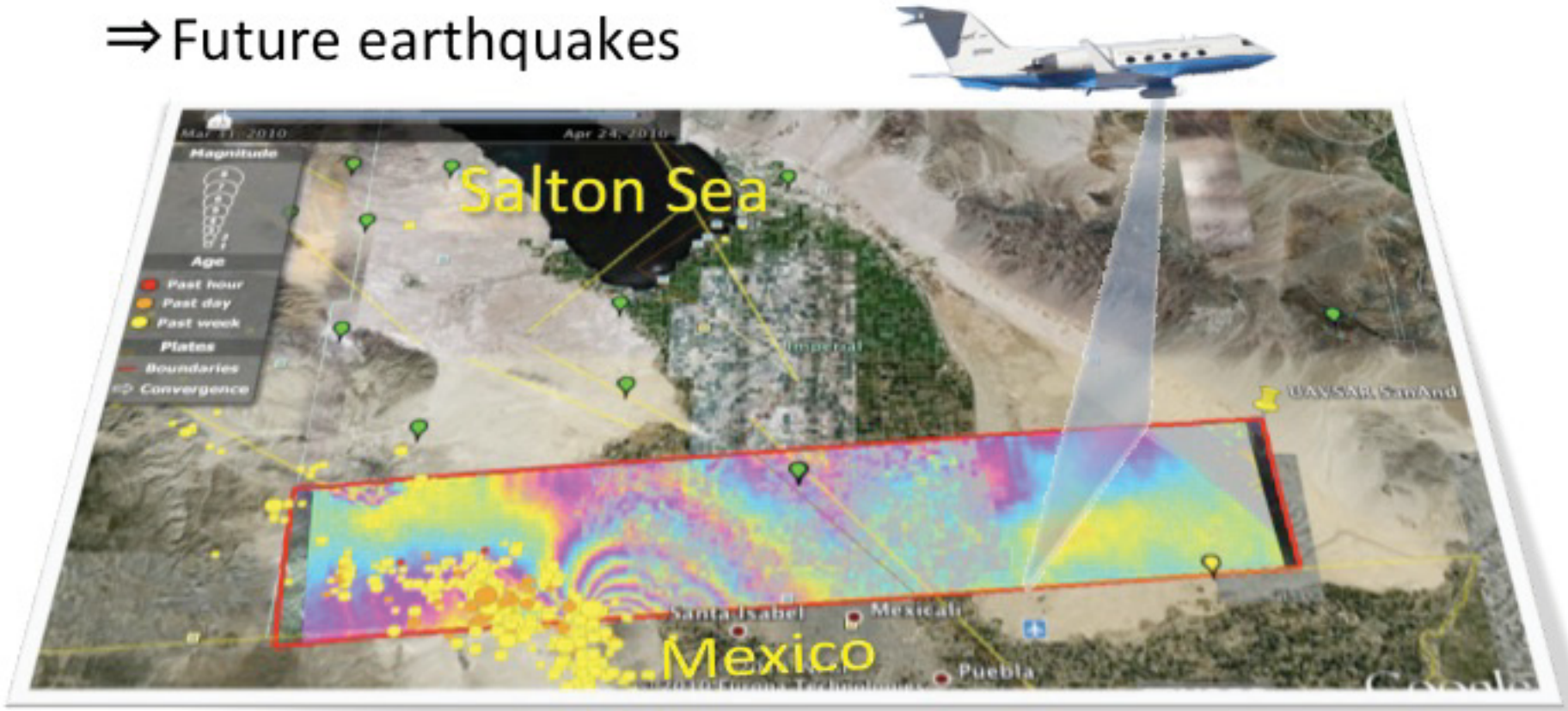
First UAVSAR Measurement of an Earthquake

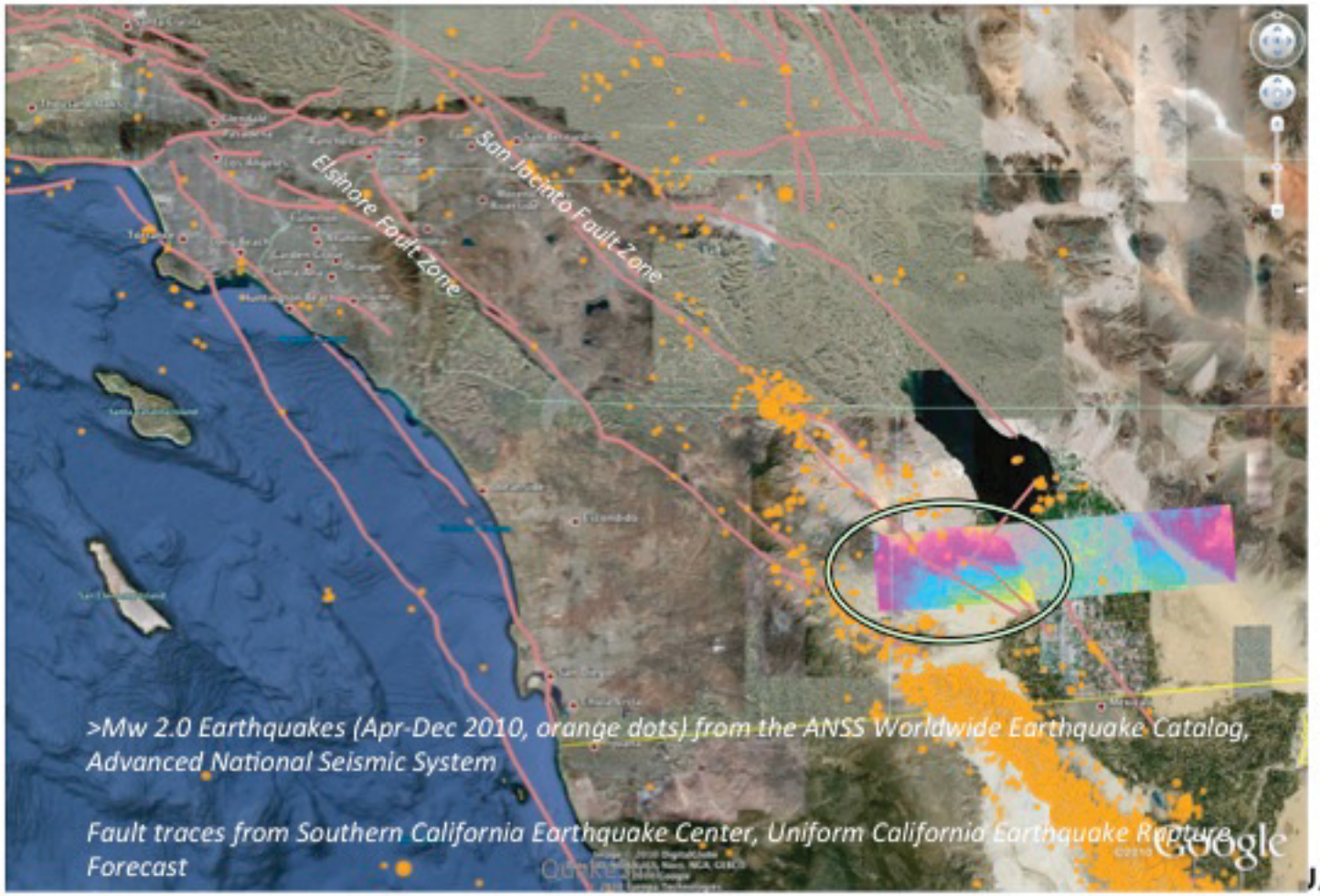
- **Response:** Displacement and disturbance maps
- **Forecasting:** Strain migration

  ⇒ Future earthquakes



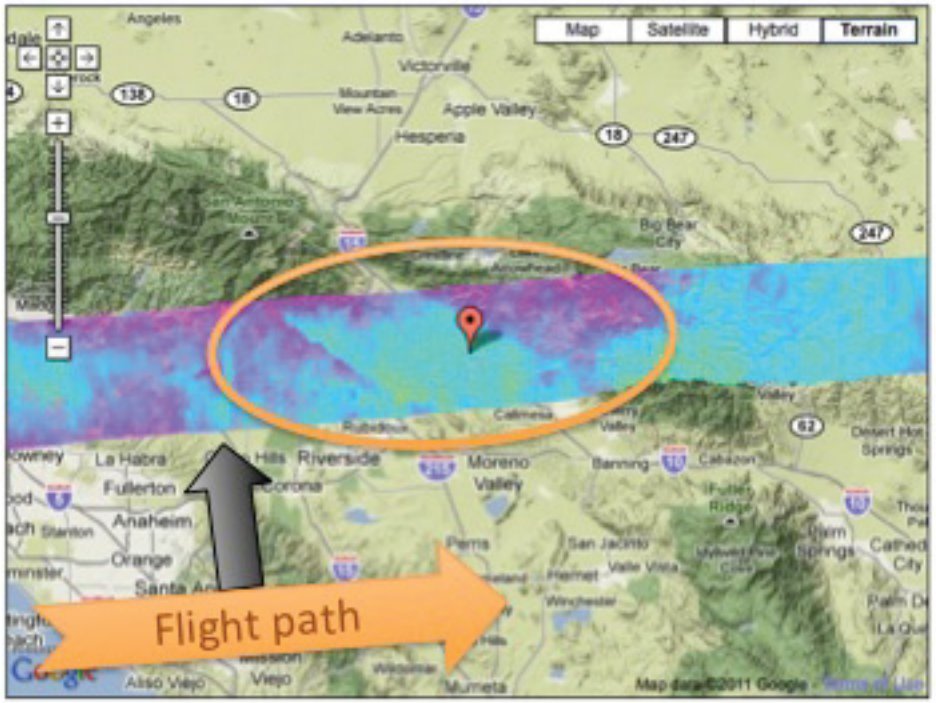
Quake Triggers Responses on Key Faults

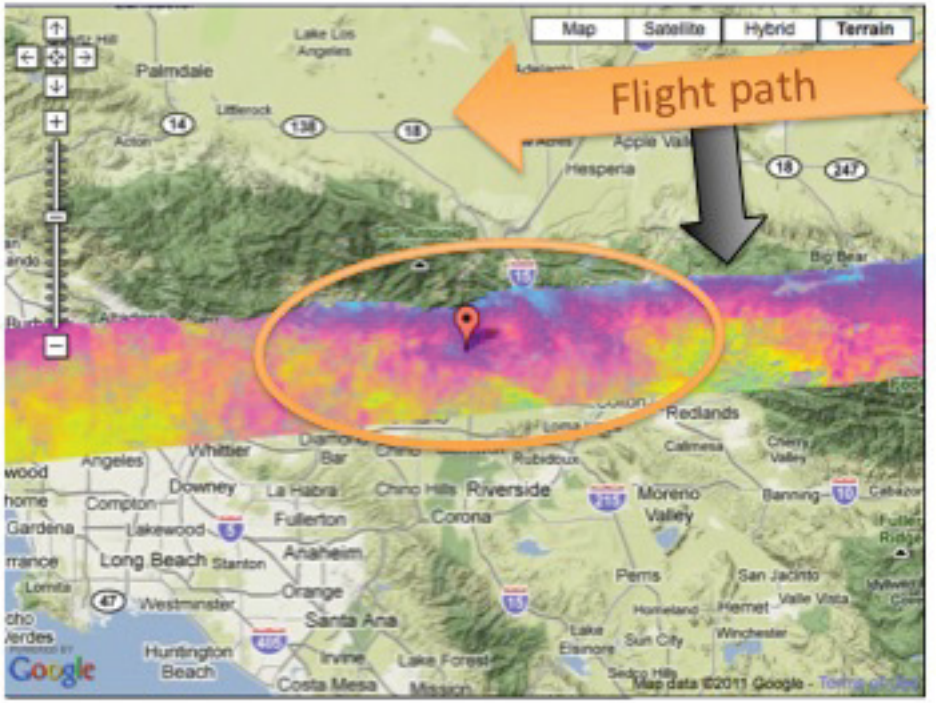
- Elsinore fault extends into Los Angeles (nearly all is historically quiet: building stress)
- San Jacinto fault reaches to San Bernardino (historic quakes are >100 yr or far south)
- Full-length ruptures must be considered: damaging earthquakes



Rialto-Colton

September 2009 – October 2010





Measure line of sight changes to airplane

- Closer looks more sensitive to vertical motion
- Farther looks more sensitive to horizontal motion

Gradient is more pronounced for data farther from aircraft

- Closer to horizontal look angle
- Suggests horizontal motions dominate => Strike-slip deformation

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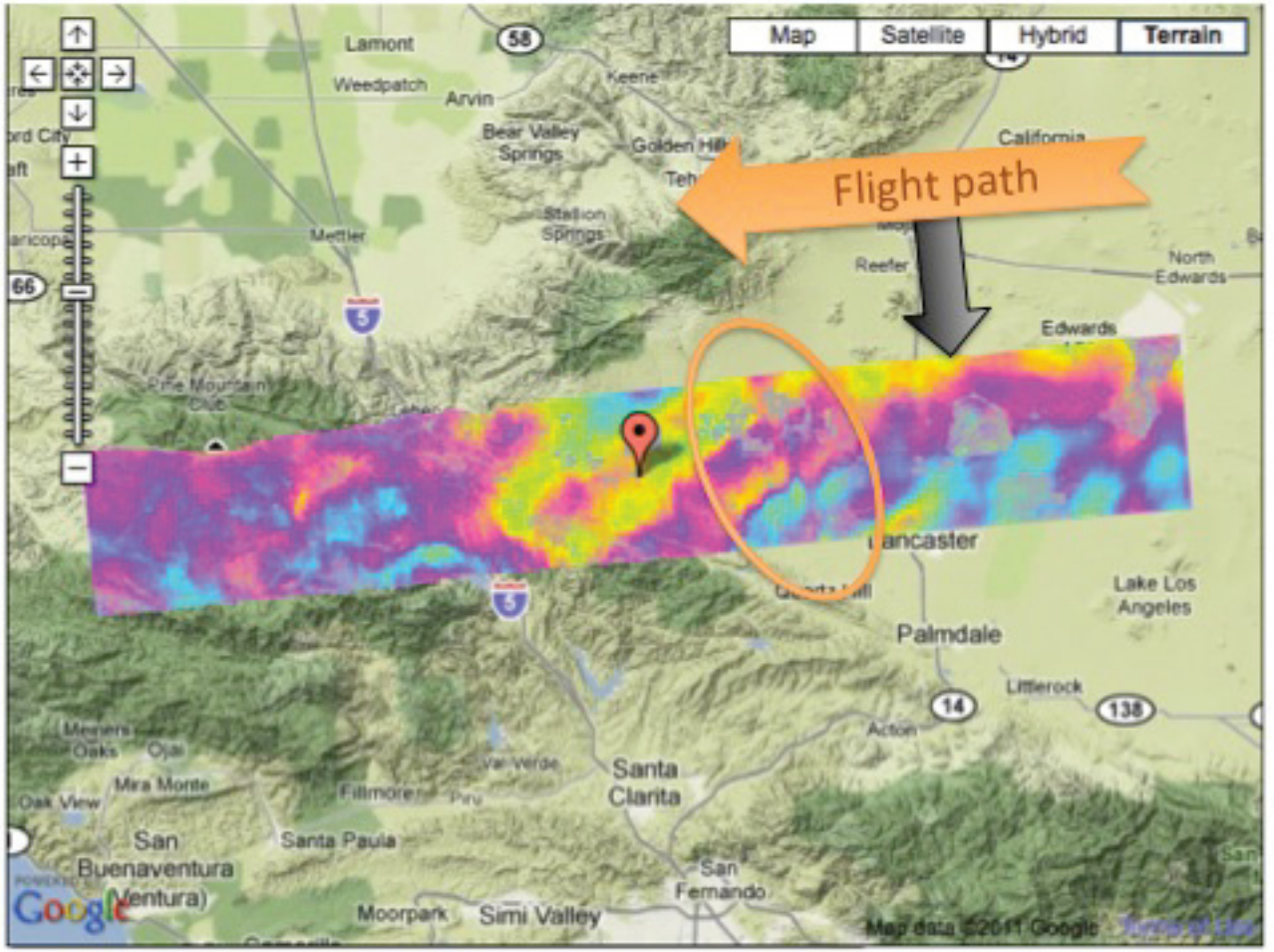
Lancaster

October 2009 – October 2010

- Sharp gradient
- Trend crosses San Andreas Fault
- Not an artifact?
  - No aircraft motion on either flight
  - Not perpendicular to flight path



GPS Velocities

Pacific Reference Frame

- Gradient west to east across Los Angeles
- Trend crosses San Andreas Fault

Plot generated by UNAVCO velocity viewer; Solution supplied by Global Strain Rate Map Project, State University of New York, Stony Brook; Kreemer, C., W.E. Holt, and A.J. Haines, An integrated global model of present-day plate motions and plate boundary deformation, *Geophys. J. Int.*, *154*, 8-34, 2003.

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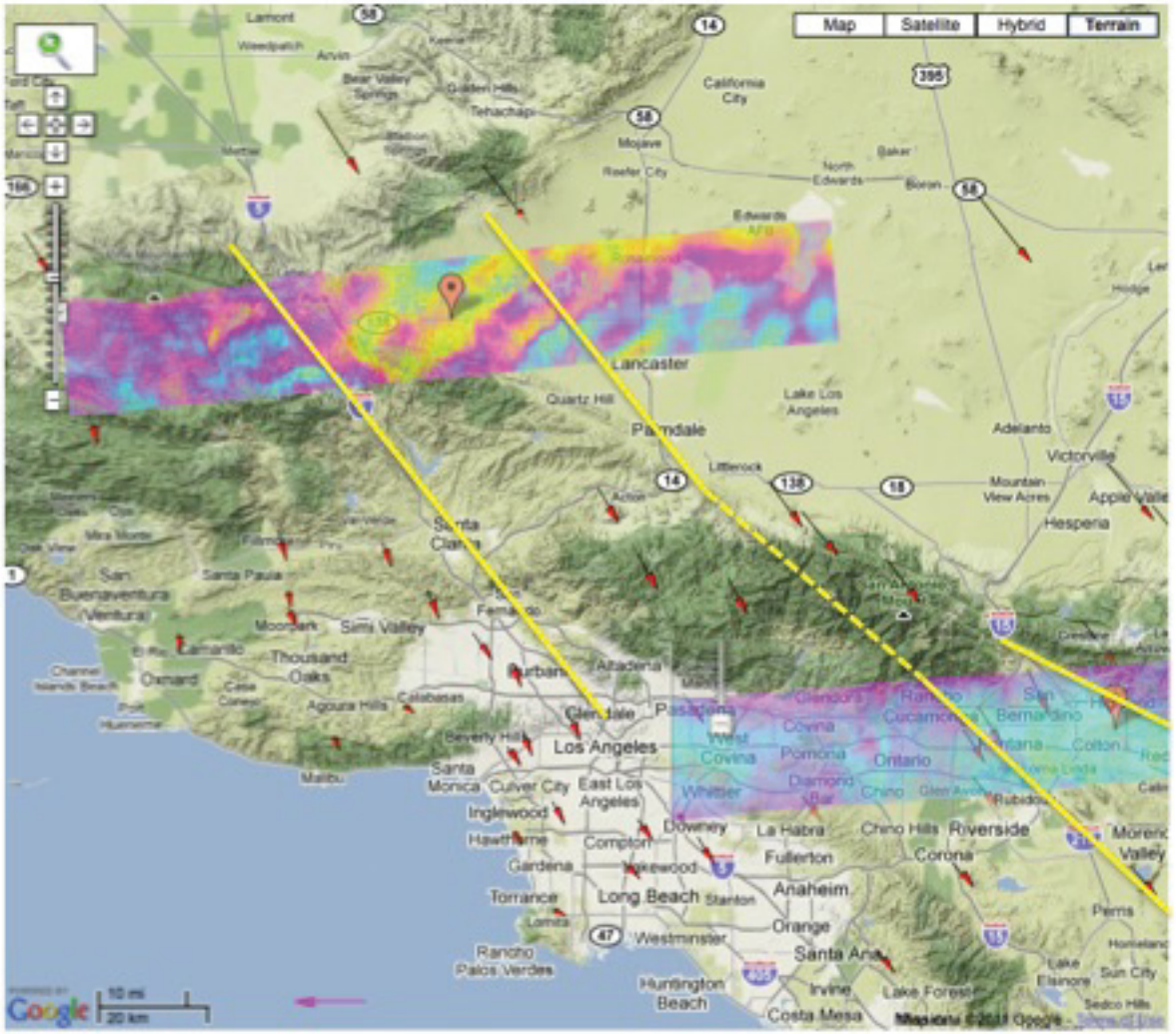
GPS Velocities and InSAR

Pacific Reference Frame

- Gradient west to east across Los Angeles
- Trend crosses San Andreas Fault north of Los Angeles
- Gradient on San Andreas east of Los Angeles



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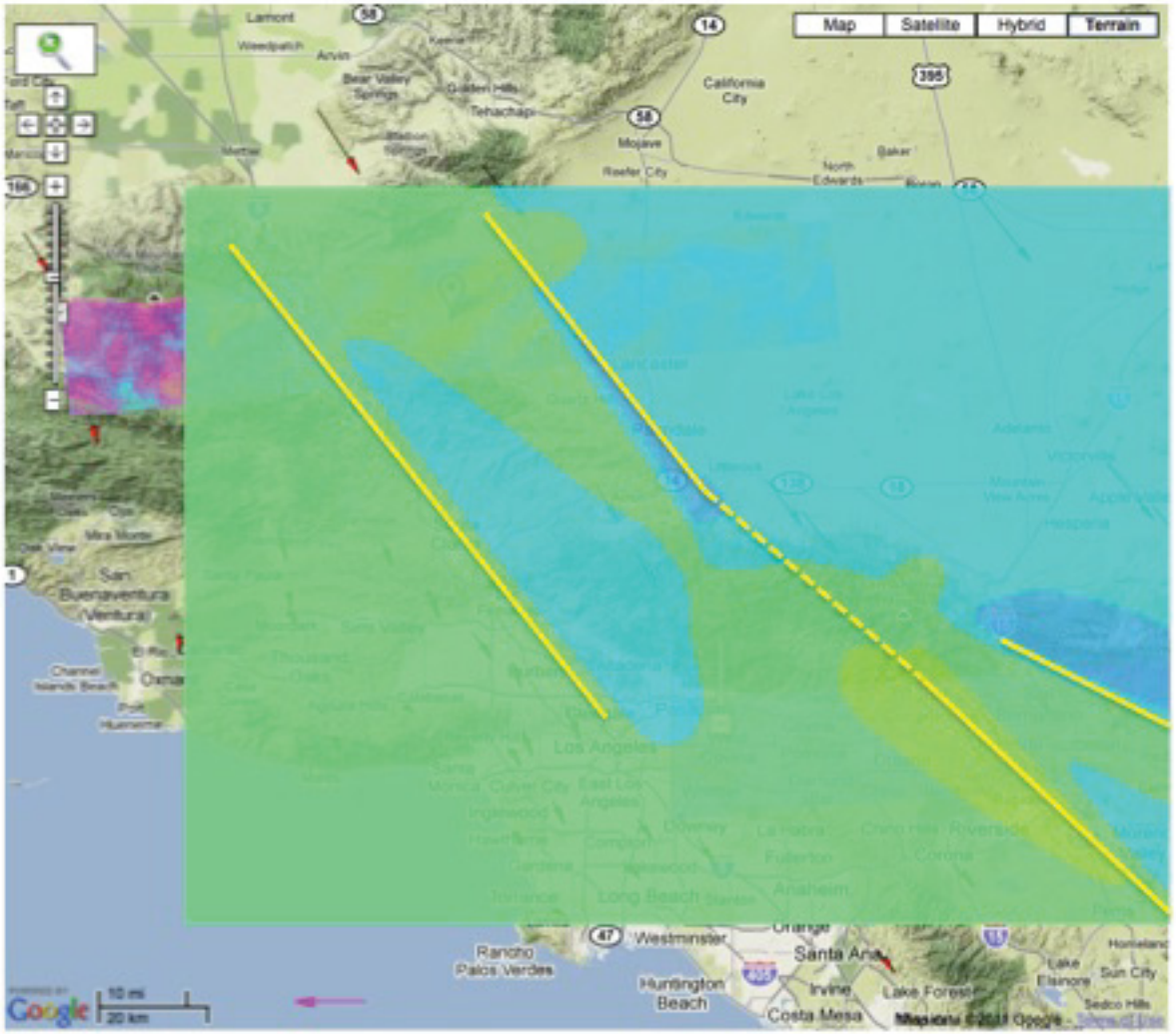

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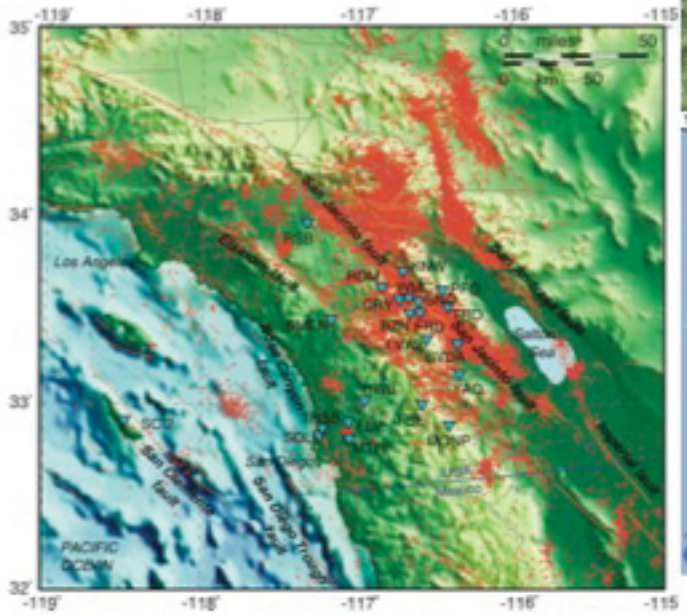
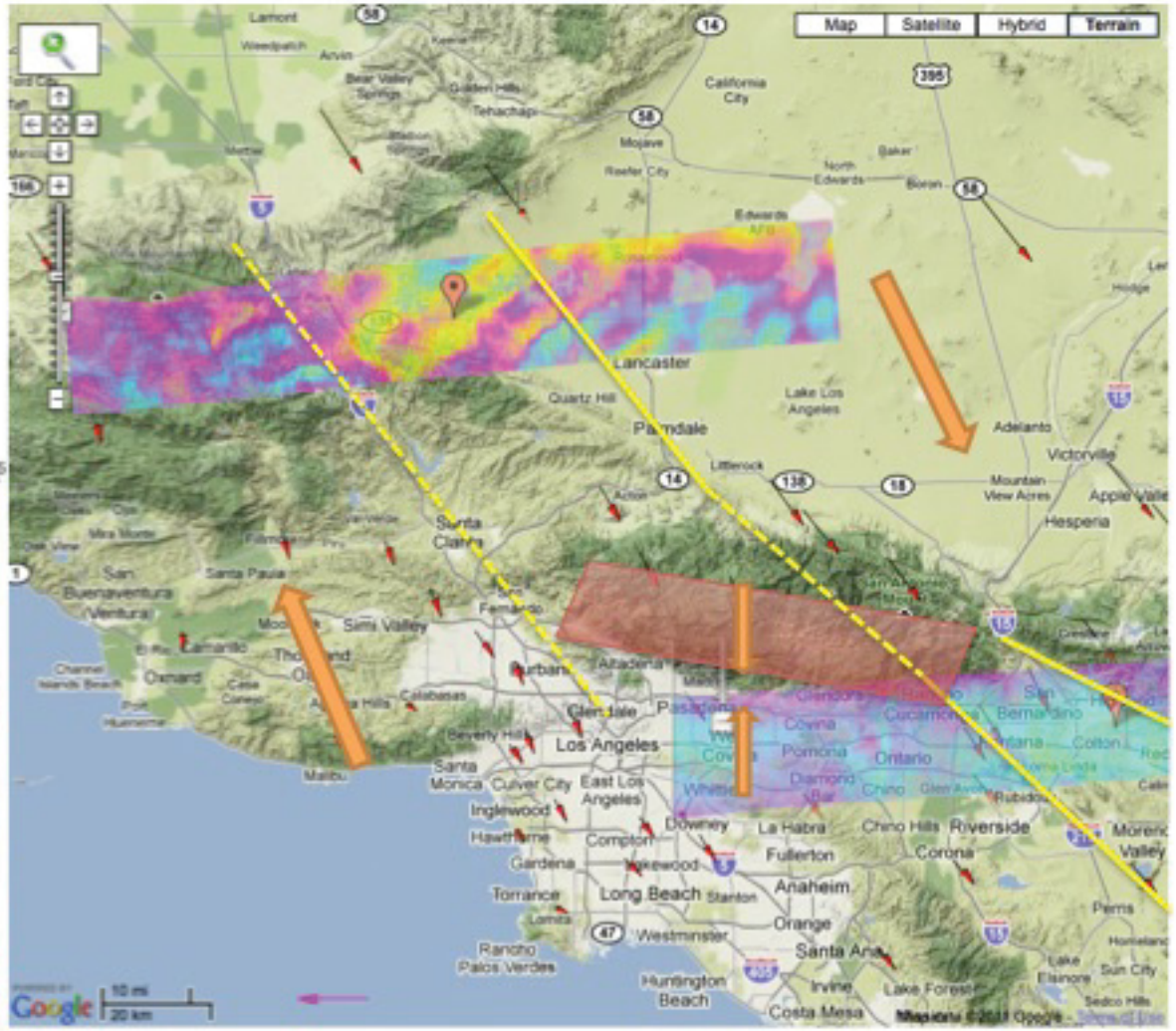
The San Gabriel Knot?

- Localized strain rates north and south of the San Gabriels
- Lots of seismicity around the San Gabriels





NASA

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The San Gabriel Knot?

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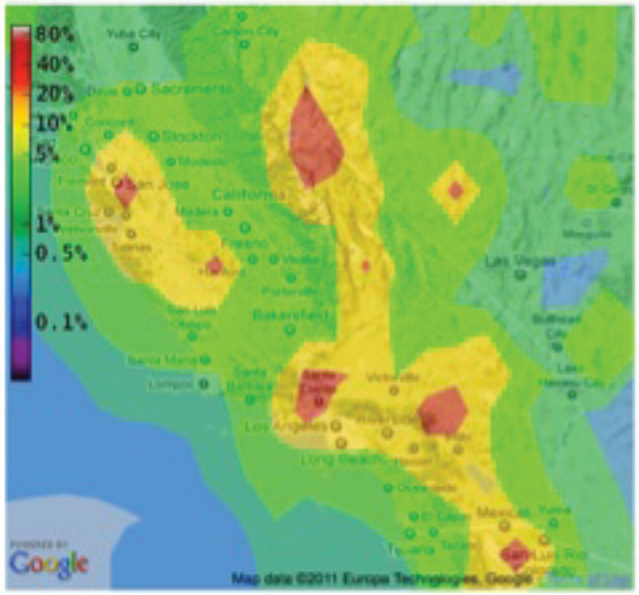

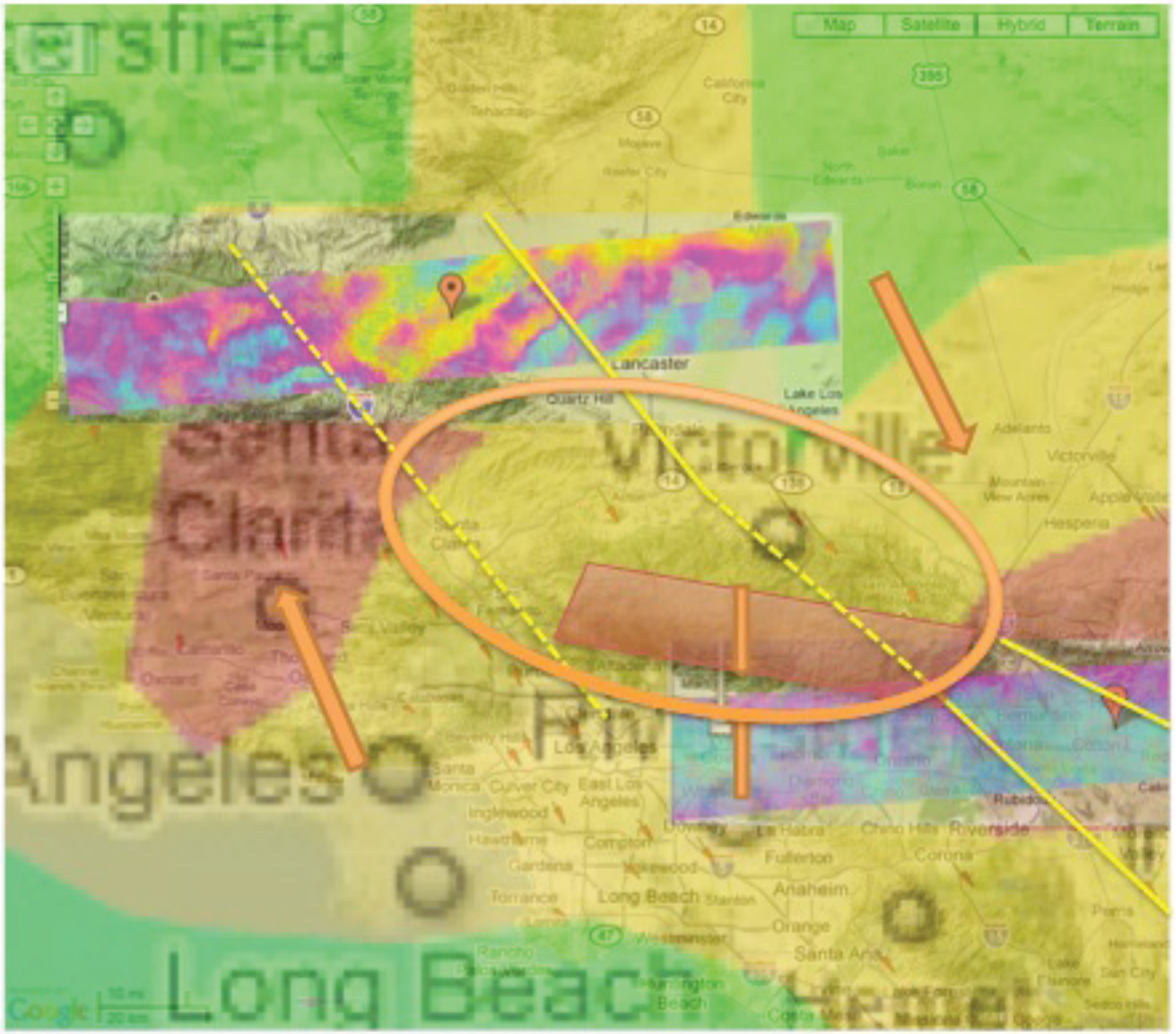

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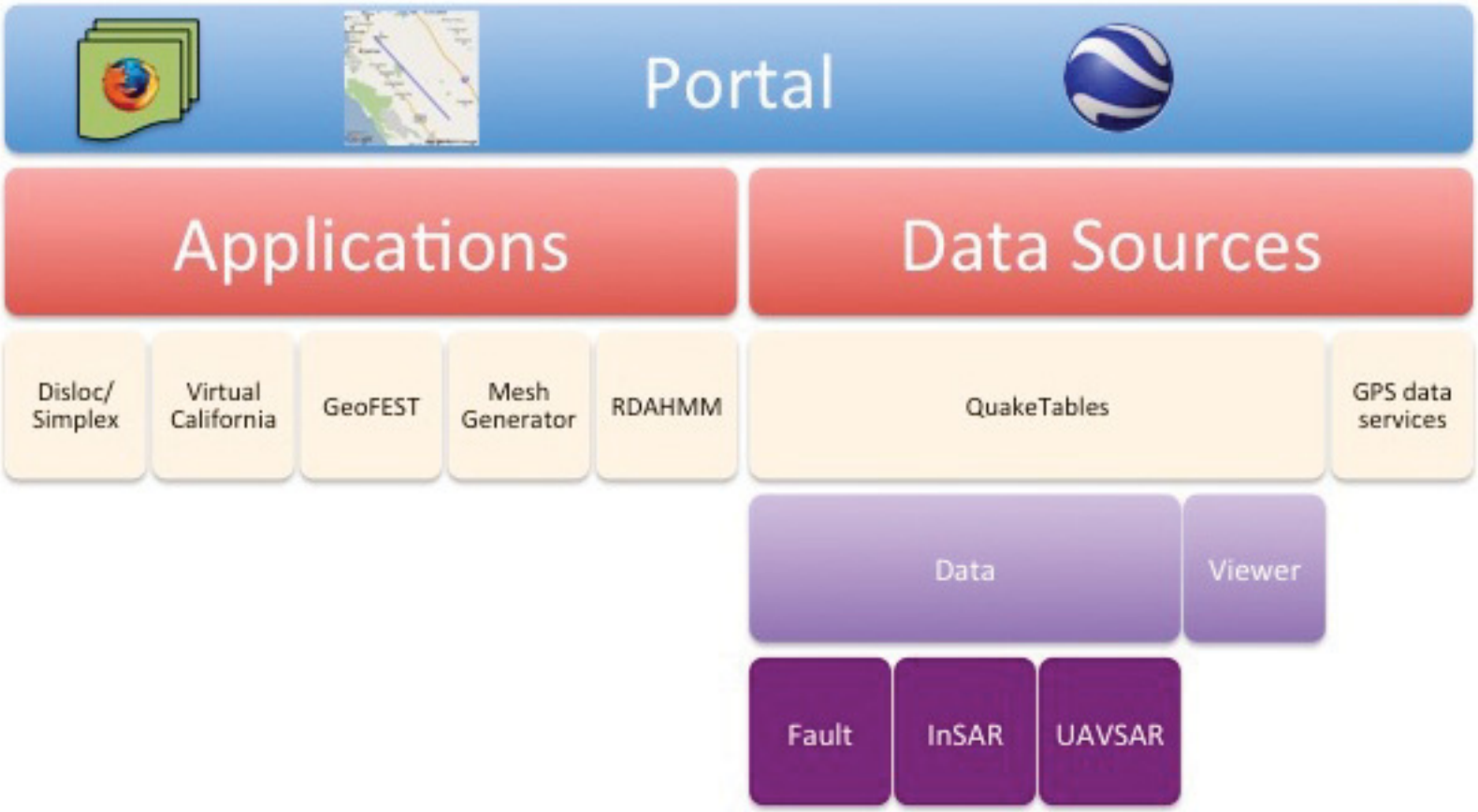
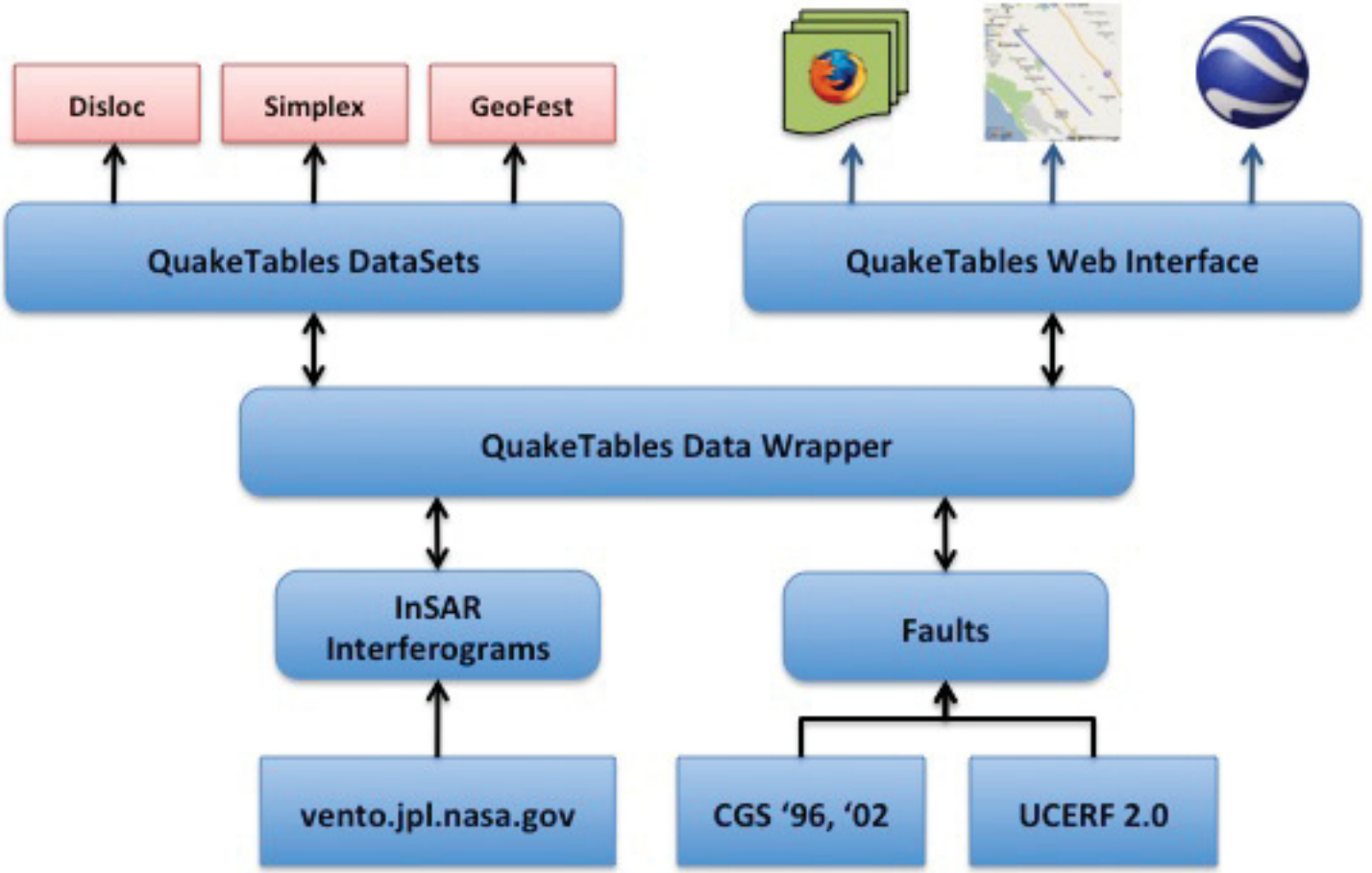
QuakeSim Architecture:
Integrating Multiple Data Sources and Applications



QuakeTables Architecture:
Integrating Multiple Data Sources

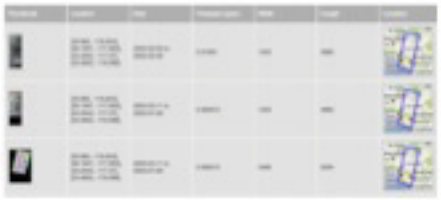


QuakeSim: Increasing Accessibility and Utility of Spaceborne and Ground Based Earthquake Fault Data

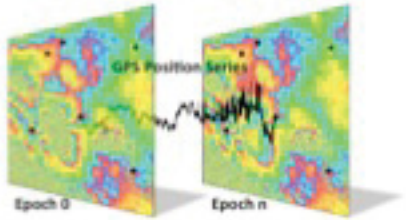
Multidisciplinary and multi-institutional

Geology
Lisa Grant (UC Irvine)

Databases
Dennis McLeod (USC)



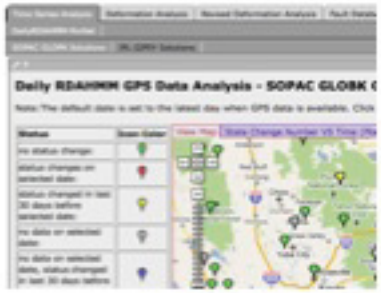
Science, Models, and Data Analysis
Andrea Donnellan, Jay Parker,
Maggi Glasscoe, Greg Lyzenga (JPL)



Grid Computing
Geoffrey Fox (Indiana U)

Future Grid

Web Services
Marlon Pierce (Indiana U)



Pattern Analysis
John Rundle (UC Davis)
Robert Granat (JPL)

High Performance Computing
Walter Brooks (NASA Ames)

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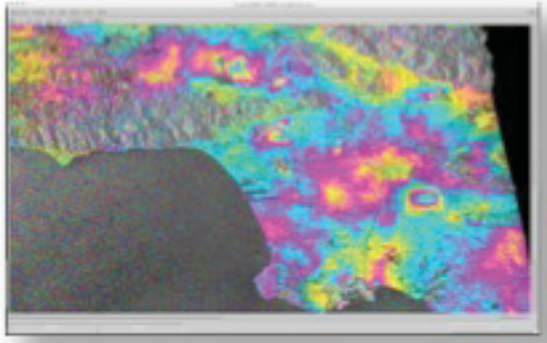
Science is Maximized through Data and Interface Standards

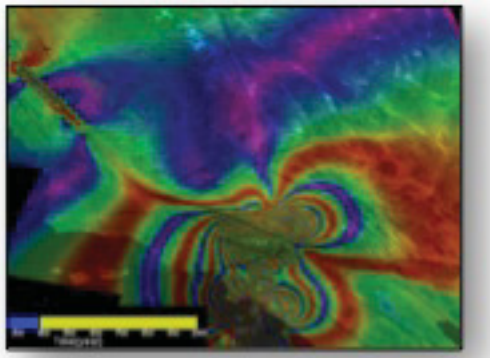
Just some of the QuakeSim interfaces

UAVSAR Solutions

InSAR Analysis



Southern California Earthquake Center Simulators Group



GPS Solutions

APEC Cooperation for Earthquake Simulation

Decision Support

E-DECIDER

NASA

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Computational Technology and Quake Simulations

The Good, the Bad, and the Ugly

- Leverages work to produce more science — Good
- Mistrust
  - Scientists often want to hold their data or tools — Ugly
- Duplicative work
  - Healthy competition often adds validation and exposes occasional errors — Good
  - Inefficient and sometimes ends up with misleading credit — Bad
- Need clearly defined roles and interfaces — Good

At this the whole pack rose up into the air, and came flying down upon her

– Alice in Wonderland

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Summary of LA Analysis

- UAVSAR and GPS observations indicate complex faulting across the Los Angeles portion of the Pacific-North American plate boundary
- UAVSAR observations show a series of linear offsets
  - Sub-parallel to the overall strike of the Pacific-North American plate boundary
  - Not the Big Bend portion of the San Andreas fault
- These lineaments suggest that structures striking sub-parallel to the Pacific North American plate boundary accommodate some of the deformation in the Big Bend of the San Andreas fault
- QuakeSim inversions and models of the data illuminate the underlying tectonic fabric of the region
- QuakeSim tools are also being used to analyze aquifer versus tectonic control of motion along these fault structures
- Long-term simulations of the southern California region suggest that earthquakes on these long faults often occur following events
  - M 7.2 El-Mayor/Cucapah earthquake that occurred in Mexico on April 4, 2010

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Infrastructure for Today and the Future

- Data deluge will continue to increase
  - Increasing diversity of data sets and sources
  - Including from future missions
- Groups should produce data products that can be readily integrated into other systems
  - Modeling and analysis
  - Decision support

Computational Infrastructure and interfaces will become increasingly important

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